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Assessment of Social Effects Generated by Railways

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ABSTRACT

Currently, the efficiency of transport systems, both at national level and while developing regional and interregional trade and cooperation links, is considered to be among most important factors for successful and sustainable economic development.

The enhancement of transport systems in many cases implies implementation of large infrastructure projects, supposing major investment and generating a series of economic and social effects. And if a few studies have already been devoted to the economic impact, the social sphere has not yet received due attention.

The paper refers to an attempt to fill this gap. The scope of the study regards passenger rail transport that has being dynamically developed in many countries and that is paid much attention in strategic documents on development of transport industry in the Russian Federation.

The objective of the study is to identify the positive and negative effects generated by projects for development of railways, and to propose approaches to their quantitative measurement.

The methods engaged in the study comprise the analysis of academic sources and methodological materials already developed abroad and in Russia, as well as relevant regulatory documents, including the methodology for assessing the socio-economic effects of transport infrastructure construction projects. This made it possible to systematise the existing social effects of railway transport into groups.

The shown examples of monetary assessment of these effects are based on the best foreign practices. The results could be useful to the investors and the public administration for making decisions on funding, as well as for evaluating the effectiveness of transport projects, which could ultimately allow to save budget funds, increase the return on investment and solve several social problems.

Keywords: railway transport, efficiency of railway projects, effects of railway transport, time saving effect, environmental effects, transport economics, noise level, social integration, well-being.

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INTRODUCTION

According to the Strategy for Development of Railway Transport in the Russian Federation until 2030[1], railways will allow the country, economy and society to achieve the following results:

• Acceleration of economic growth.

• Reduction of transport costs for business entities and release of funds for development of other areas of the domestic economy.

• Provision of conditions for development of territorial industrial and scientific clusters.

• Levelling of disproportions of inter-regional development.

• Ensuring trade links between economic centres.

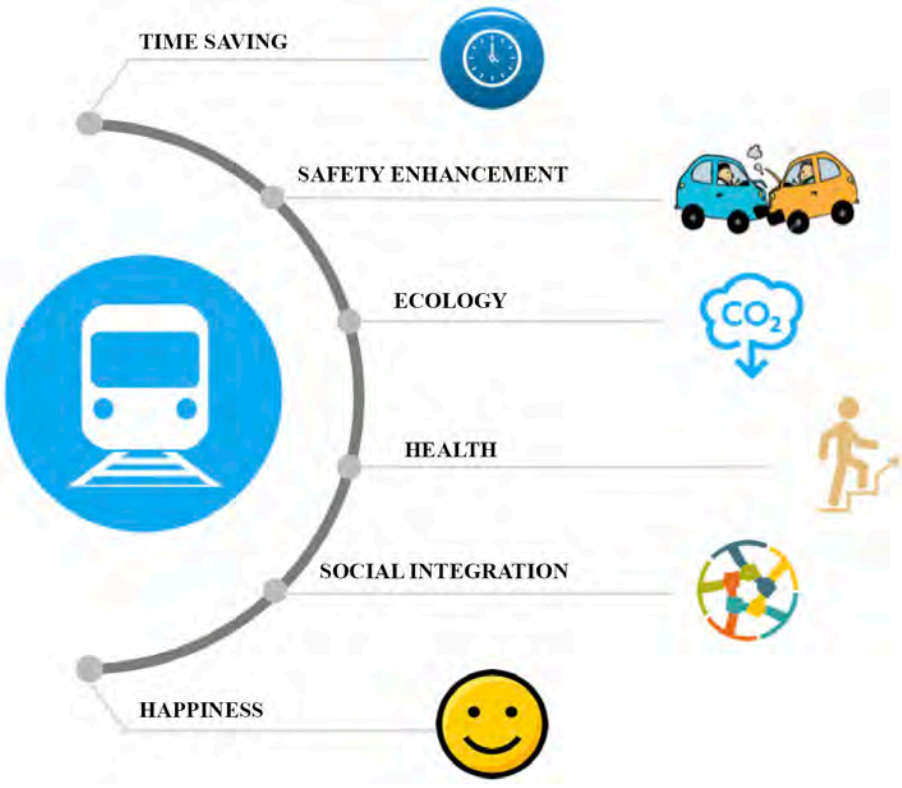
• Increasing the competitiveness of the Russian economy and the attractiveness of the country for business development and investment inflows.

• Development of transport mechanical engineering and other interrelated sectors of the economy.

[1] Strategy for Development of Railway Transport in the Russian Federation until 2030: approved by the Order of the Government of the Russian Federation dated June 17, 2008 No. 877-r. [Electronic resource]: https://mintrans.gov.ru/documents/7/1010. Last accessed 14.09.2022.

Most of the research is devoted to assessing the economic effects of railway transport; namely, the works of L. V. Lapidus [1], D. A. Macheret [2], of the Centre for Strategic Research [3] and O. N. Frolova [4] can be mentioned. However, the international experience shows that the impact of transport infrastructure projects is not limited to the economy and affects the social sphere.

The *objective* of the study is to reveal the effects generated by projects for development of railway transport for the economy and the social sphere, and to propose approaches to their quantitative measurement. *Methods* used during the study have comprised an integrated approach and empirical-theoretical methods, that have allowed to conduct a study based on the aggregate characteristics of projects for development of railway transport. The work has used open statistical data, analysed academic sources and methodological materials already developed abroad and in Russia, as well as regulatory documents, including methods for assessing the socio-economic effects of transport infrastructure construction projects, approved by the Decree of the



Pic. 1. Positive effects generated by infrastructure projects on railway transport [compiled by the author].

Government of the Russian Federation of November 26, 2019, No. 1512.

RESULTS

Economic Effects

Studies of economic effects allow us to estimate the share of a particular industry in the economy at a certain point in time and give an idea of their relationships. In this case, the generated effects are divided into direct and indirect ones. The former effects are measured in terms of gross value added (GVA), which is the difference between the cost of an industry's output and the cost of the inputs necessary to produce it. Indirect effects consider the demand that is formed in sectors that produce resources for the railway industry and supply it. For example, a railway operator may purchase telecommunications equipment, which will increase demand in that sector and in turn will require plastics, metals, and other materials to manufacture the equipment. With an increase in transportation volumes, there is a corresponding increase in the costs of intermediate products (fuel, electricity, materials, etc.), which leads to an increase in production in related industries. Further, through the costs of related industries, there is growth in almost the entire economy. The increase in gross output is accompanied by a corresponding increase in income: in taxes, wages, profits, which are redistributed and transformed into an increase in the final demand of the state, business, and the population [5].

The real estate market should be singled out as one of the important areas of impact: construction of new infrastructure can lead both to a fall in real estate prices (due to an increase in noise levels, changes in scenic view parameters, environmental pollution) and to their growth (improvement of transport accessibility and time saving) [6].

The cumulative economic effect of investments consists of increments in gross output by sectors of the economy at the investment stage and at the operation stage and consists of three elements[2]:

1. Growth in the gross value added of the industry that provides the output of the *i*-th type of national products.

2. Growth in gross value added created by the trade and transport industries that provide the supply of the *i*-th type of product.

3. Growth in gross value added created by related sectors of the economy that provide the production of the *i*-th type of national products.

At the operational stage, a fourth element is added to them:

4. The increase in gross value added created by the direct participant in the infrastructure project at the operational stage, which is calculated through the total increase in revenue of the direct participant in the infrastructure project from the sale of goods, works, services of the *i*-th type.

Social Effects

Despite the importance of evaluating economic effects, the impact of railway projects on the social sphere cannot be ignored. This influence can be both negative and positive. As a rule, any transport projects are associated with the following negative impacts:

- Accidents.
- Environmental pollution.
- Climate change.
- Increase in noise level.
- Growth of energy production costs.
- Negative impact on nature and landscape.

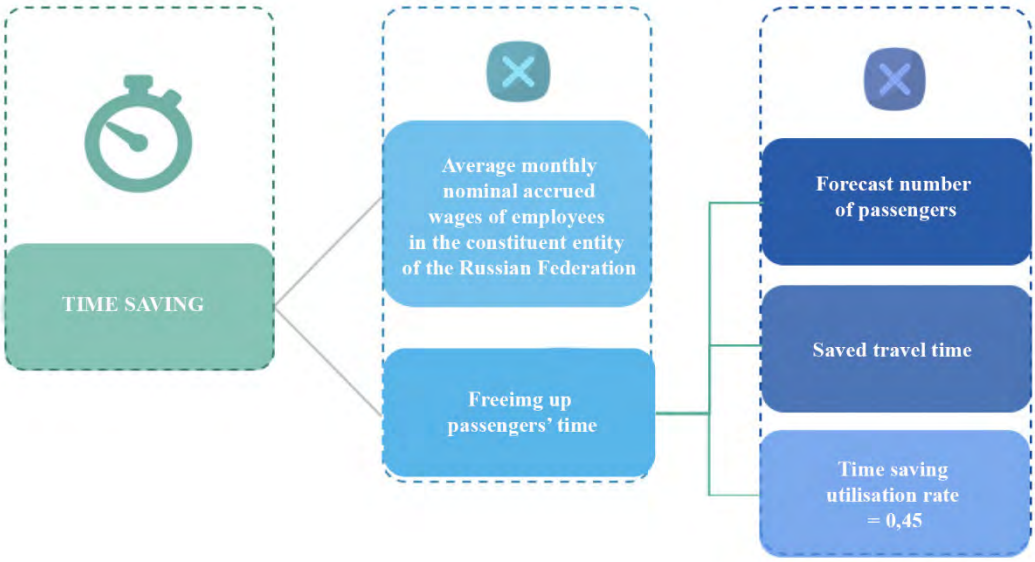
However, with an alternative choice, different projects (modes of transport) can also generate a positive impact (Pic. 1):

- Travel time saving for passengers and haulage.
- Improving the safety of passenger and cargo transportation.
- Reduction of emissions of harmful substances and noise level (when choosing alternative options).
- Beneficial effects of public transport due to increased physical activity.
- Social integration and barrier-free environment.
- Subjective wellbeing – the perception of the world around, or the level of happiness.

The final effect of the project implementation can be obtained by comparing the potential benefits and costs, including through a comparison of various alternatives.

The monetary assessment of the last four effects is complicated by intangible nature and

[2] Methodology for assessing the socio-economic effects of construction (reconstruction) and operation of transport infrastructure facilities planned for implementation with involvement of federal budget funds, as well as with the provision of state guarantees of the Russian Federation and tax benefits: approved by Decree of the Government of the Russian Federation dated November 26, 2019, No. 1512.



Pic. 2. Calculation of the monetised effect of travel time saving for passengers [compiled by the author].

is not provided for by the Methodology approved by Decree of the Government of the Russian Federation of November 26, 2019 No. 1512.

Time Saving[3]

Reliable and fast travelling (and, consequently, high availability) in large cities with a population of more than 250 thousand people can only be provided by public transport, the development of which should be focused on achieving the following consumer properties [5]:

• Reliability (guaranteed share of trips in accordance with planned waiting and trip times).

• Accessibility (geographical availability and price affordability).

• Comfort.

Calculations of the socio-economic effects generated by implementation of projects for development of urban public transport systems use quantitatively measurable indicators that are directly related to the projects. First, these parameters include the time saved by passengers. This effect is formed by the following elements (Pic. 2):

• Saving of passengers' time during implementation of the infrastructure project, that is estimated depending on the region and route.

• Average monthly nominal accrued wages of employees in the constituent entity of the Russian Federation where the infrastructure project is being implemented.

Thus, for the assessed railway project, the time savings of passengers attracted from road and urban passenger transport (metro, surface urban transport and intercity passenger transport) can be estimated. The quantification of time saving effects depends on several factors:

• Points of departure and destination.

• Time of day when trips are made.

• Transit capacity and layout of the road network.

• Location of stations.

• Frequency of railway transportation.

• Available alternative modes of transport: buses, walking and cycling routes.

These factors vary from city to city and change over time. As a rule, time saving effects are estimated using models that simulate the transport network and its operation in a particular city or locality. According to a study by Deloitte [7], in Australia, every car trip that is replaced by a railway trip reduces travel time for other road users by about 7–27 minutes. For example, for Sydney this means the following: if all trips of a person to and from work are transferred from car to railway, the savings in time for other road users will be 3 days and 18 hours per year; for 1000 people it will make 10 years and 3 months.

The opportunity costs of travel time (which could otherwise be used for other purposes) can also be estimated. In Australia, business

[3] The assessment should take into account the type of railway transport; in this study only passenger traffic is considered.

Table 1

Correction factors for accounting of unregistered accidents

	Deaths	Serious injuries	Minor injuries
Cars, buses	1	1,25	2
Motorcycles	1	1,55	3,2

Sources: [8; 9].

travel time is estimated at 129,8 % of average weekly income (AWE) and travel time to and from work and the time of all other trips is estimated at 40 %. Assuming 10 % of trips are for business purposes, the weighted average value of time saved per trip is estimated at $ 20 (private trips at $ 16,32, business trips at $ 52,96).

The monetised travel time savings effect for the economically active population is calculated as the sum of discounted travel time savings. The average coupon rate of bonds of the region where the project is being implemented can be used as the discount rate.

It should also be considered that traffic congestion increases fuel consumption and, as a result, leads to air pollution and greenhouse gas emissions, which entail additional costs for the entire society. Ecological effects will be discussed in more detail in a separate section.

Safety Improvement

Accidents affect all modes of transport and lead to significant costs, which are divided into five main components:

• Evaluation of pain and suffering caused by traffic accidents. In the case of injuries, these costs cover the pain and suffering of the victim, and in the case of deaths, the loss of the victim' utility.

• Medical costs: the cost of treating injured accident victims, including the cost of equipment and medicines. Medical expenses cover the period from the time of the accident until full recovery from the injury or, in the case of a fatal accident, until death. In many cases, some of these costs are already included in insurance payments.

• Administrative costs: costs covering the costs of the police, the Ministry of Emergency Situations and other emergency services (except health services) providing assistance at the scene of an accident. In addition, this category includes costs related to justice: legal costs, costs of prosecution of offenders, costs of litigation and insurance. Finally, this category also includes administrative costs related to vehicle or health insurance.

• Loss of productivity: after an accident, victims cannot immediately return to work (or they never return to it). These costs consist of net production losses caused by reduced working hours and the cost of replacing human capital. The inability to perform «non-market» work, such as housework or volunteering, is also included in this cost component.

• Property damage consists of the monetary value of damage to vehicles, infrastructure, cargo, and personal property resulting from accidents. It is assumed that this component is fully considered by road users through insurance.

• Miscellaneous costs: This category covers expenses related to traffic congestion, unavailability of vehicles and funeral arrangements. In European practices, this category of costs is not considered since most of them are taken into account through other categories of external costs, or do not belong to external costs at all.

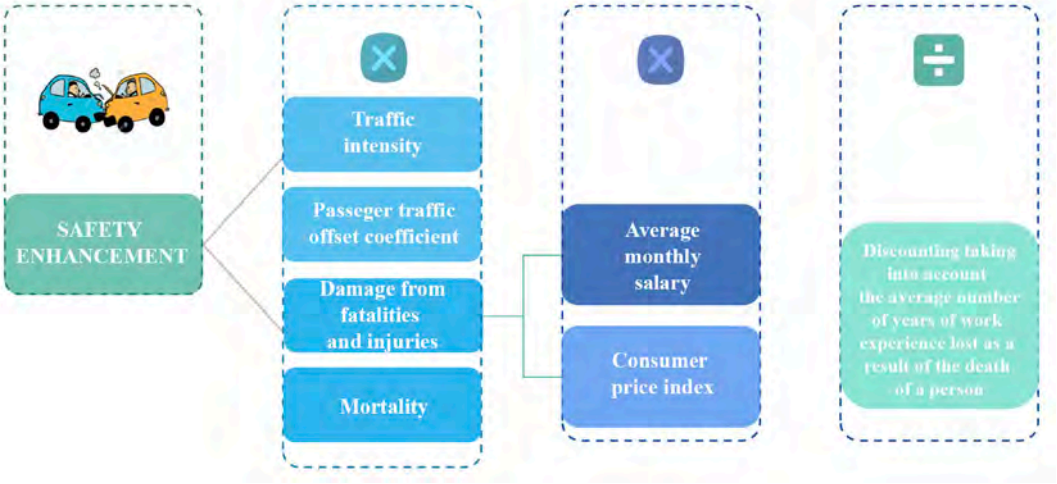
Accident prevention costs are not included in the cost of accidents because they are not (directly) the result of road traffic accidents but are intended to reduce the accident rate. In addition, they are (partially) included in road infrastructure costs.

It should be noted that the mortality and the number of injured in official statistics reflect only registered accidents. However, some road accidents are not registered. In European practices, official data on road traffic accidents are adjusted to account for these unreported crashes. The applied correction factors are presented in Table 1.

According to the Methodology approved by the Government of the Russian Federation, the assessment of losses resulted from road traffic accidents is based on the following parameters (Pic. 3):

• Average annual traffic intensity, passengers/day.

• Coefficient of displacement of passenger traffic from the existing to the proposed route



Pic. 3. Calculation of the monetised effect of saving travel time for passengers [compiled by the author].

during the implementation of the infrastructure project.

• Average socio-economic damage from fatalities and injuries resulted from road traffic accidents.

• The number of deaths and injuries in road traffic accidents per 1 million passengers per year.

The key variable in this case is the offset coefficient: rate of displacement of passenger traffic from the existing to the proposed route of movement. Reducing travel time and improving service when using railway transport have a significant impact on attracting additional passenger traffic, including previously immobile population, as well as on increasing the mobility of the existing and prospective populations gravitating towards railway lines.

Environmental Effects

In terms of environment, there are several areas of impact:

1. Air emissions.
2. Noise level.
3. Energy production costs.
4. Impact on nature and landscape.

Emissions of pollutants into the atmosphere can lead to several types of damage [10]:

• Health effects: inhalation of air pollutants such as PM10, PM2.5 particles and nitrogen oxides (NO_x) increases the risk of respiratory and cardiovascular diseases (e.g., bronchitis, asthma, lung cancer). These negative health outcomes result in medical costs, job losses and, in some cases, death.

• Yield losses: ozone as a secondary air pollutant and other acidic air pollutants (e.g., SO_2, NO_x) can damage crops, entail lower yields (e.g., of wheat).

• Property and building damage: air pollutants can lead to (a) contamination of building surfaces; to (b) damage to building facades and materials due to corrosion processes caused by acidic substances (for example, nitrogen oxides NO_x or sulphur oxide SO_2).

• Loss of biodiversity: air pollutants can damage the ecosystem by (a) acidification of soil, precipitation and water (e.g. NO_x, SO_2) and by (b) pollution of waters by algae (e.g., NO_x, NH_3).

Different modes of transport are characterised by different levels of harmful emissions. As can be seen from Table 2, from an environmental point of view, railways have a clear advantage.

Noise emission from transport is a growing environmental problem due to a combination of a trend towards greater urbanisation and an increase in traffic volumes. While increased traffic leads to higher noise levels, growing urbanisation means that more people experience noise discomfort. In the future, the negative effects of road noise may increase despite potential improvements in related vehicle performance. In general, noise can be defined as unwanted sounds of varying duration and intensity that cause physical or psychological harm to a person.

Noise level is measured in decibels (dB). Within the human hearing range, deep and very high tones of the same intensity are perceived as less noisy. Decrease or doubling the amount of traffic results in a 3 dB change in noise level, regardless of the current traffic. That is, an increase in traffic volume from 50 to 100 vehicles

Table 2

Air pollution costs

Mode of transport	€-cent / passenger-kilometre	€-cent / car-kilometre
Car	0,71	1,14
– petrol engine	0,33	0,53
- diesel engine	1,18	1,9
Motorcycle	1,12	1,17
Bus	0,76	14,19
Intercity bus	0,73	14,34
High speed passenger train	0,002	0,66
Passenger electric train	0,01	1,14

Source: [10, P. 50].

leads to the same increase in noise levels as an increase from 500 to 1000 vehicles. An important aspect is the time of day when noise occurs. It is assumed that evening and night noise causes more inconvenience than noise during the daytime [11].

The thresholds above which noise is considered a nuisance are somewhat arbitrary, with the most commonly used values being 50, 55 and 60 dB. In this case, the choice of the threshold has a significant impact on the estimation of marginal costs. Several studies have all shown that railway noise is perceived as less nuisance than road noise. Therefore, a «discount» of 5 dB can be given to railway transport when identifying the threshold rate. However, in European practices, this approach is not used [10].

Noise exposure has a negative impact on health and can lead to development of the following diseases [11; 12]: ischemic heart disease; stroke; dementia; hypertension; irritation.

Annoyance is the anxiety that people experience when they are exposed to traffic noise. It can interfere with certain activities, which can lead to various negative reactions, including frustration, anxiety, exhaustion, and sleep disturbance [12]. However, irritation is measured differently than other «classic» health effects and is therefore considered separately. The following additional negative effects may occur: loss of performance productivity (e.g. due to loss of concentration), impact of traffic noise on the environment (e.g. harmful effects on wildlife), direct material losses due to vibrations.

To be able to attribute total noise costs to each mode of transport, it is necessary to know the total number of kilometres travelled by each type of vehicles. However, noise from some types of vehicles (e.g., trucks) is considered more annoying than noise from others (e.g., cars).

Besides the direct externalities generated by transport, there are several indirect *costs of energy production*. Vehicle production, infrastructure construction, maintenance and disposal all lead to the release of air pollutants, greenhouse gases, toxic substances, and other negative environmental impacts. By far the most significant impacts are the emissions associated with energy production: extraction of energy sources, processing (e.g., refining, or power generation), transportation and transmission, construction of related infrastructure. The effect of energy production is very important, first, for electric vehicles since there are practically no emissions during their operation.

There are two types of input values for calculating the energy production costs: emissions of harmful substances and damage from the monetisation of emissions. The former costs include emissions of greenhouse gases and air pollutants generated during energy production. The costs of monetising emissions consist of the costs of air pollution and the costs of climate change.

The negative impacts of transport on nature and landscape can be described in the following terms:

• Loss of habitat: transport infrastructure requires land and/or natural surfaces. Consequently, transport infrastructure leads to the loss of natural ecosystems, which are the life environment for plants and animals. Habitat loss occurs during the construction phase of transport

Table 3

Noise-related costs per different modes of transport

Mode of transport	€-cent / passenger-kilometre	€-cent / car-kilometre
Car	0,6	0,9
- petrol engine	0,5	0,8
- diesel engine	0,6	0,9
Motorcycle	9	9,4
Bus	0,4	8
Intercity bus	0,2	4,7
High speed passenger train	0,3	97
Passenger electric train	0,8	106

Source: [10, P. 81].

infrastructure but will continue throughout the life of the infrastructure.

• Habitat fragmentation: transport infrastructure can also have additional effects expressed in fragmentation and separation for animals. These fragmentation effects can negatively affect the natural habitat of certain species and lead to adverse consequences for them. Habitat fragmentation adversely affects large wild mammals such as deer, as well as rabbits, badgers, etc., and smaller animals such as amphibians.

• Habitat degradation due to emissions: habitat degradation can also occur due to the release of other toxic substances (e.g., heavy metals) into the atmosphere.

Health Effects

The use of public transport can have a positive impact on the health of population through the additional physical activity required to get to a public transport stop and then to the final destination. For example, using data from Australian public transport riders, Barr [*et al*] [13] found that public transport availability positively correlated with recommended walking levels. The health benefits associated with physical activity tend to result in reduced risk of cardiovascular disease, type 2 diabetes, certain cancers, and osteoporosis. Other health benefits include reduced obesity, decrease in high blood pressure and high cholesterol levels, and mental health benefits.

According to Deloitte [7], walking generates benefits ranging from $ 0,41 to $ 2,29 per kilometre (2015–2016 prices). The Infrastructure Australia, based on a willingness-to-pay study, determined this value to be $ 2,93 per kilometre (2015–2016 prices). This cost reflects the value people are willing to pay to reduce morbidity and mortality.

The main difficulty lies in quantifying the total annual distance walked by train users. In Sydney, for example, they walked 301 million kilometres in 2016, generating $ 881 million in health benefits, or $ 6,62 per train passenger.

Social Integration

Transport infrastructure is fundamental to achieving social inclusion by reducing barriers that make it difficult for people to fully participate in the life of the society. Mobility is a key aspect of social inclusion and characterises the ability to access work, education, health care, shops, other public services and participate in social activities.

Compared to the individual car or motorcycle, which are expensive to own, register, and insure, and are out of reach for the very young and older people, rail transport looks favourably. The UK Department for Transport identifies the following main groups potentially benefiting from local public transport [14]:

• People with low incomes and the unemployed, including part-time workers and people claiming government benefits.

• People living in remote (rural) areas.

• People with disabilities, including people with physical disabilities, sensory impairments, and people with mental disorders.

• Elderly people.

• Youth and children.

Monetary assessment of social inclusion is most often carried out using the willingness to pay (WTP)

Effects			
Accidents	4,5	1	0,5
Air pollution	0,7	0,8	0,01
Climate change	1,2	0,5	0
Noise	0,6	0,4	0,8
Congestion	4,2	0,8	0
Energy production (Well-to-Tank)	0,4	0,2	0,8
Habitat Damage	0,5	0,1	0,6

Pic. 4. Assessment of the negative effects of infrastructure projects in the field of passenger transport in Europe, 2016 [10, P. 160].

methodology. Stanley [*et al*] [15] conducted a series of personal interviews in Melbourne with 443 adults. The results of the survey showed that people at increased risk of social isolation make fewer trips per day. For an average household income level, the willingness to pay for an additional trip is up to $ 20 (2010 adjusted prices). This score decreases as income increases since people with higher incomes tend to make more trips.

Perception of Life and Level of Happiness

The study of the so-called «wellbeing» is usually based on surveys of the population and the willingness of citizens to pay for certain improvements, including in transportation.

For example, Prud'homme [*et al*] [16] developed a public transport congestion cost curve for the Paris metro based on 2009 data. Estimated willingness to pay for free travel (without congestion) was equal to 1,43 euros per trip.

A study by Clark [*et al*] [17] showed that an increase in one-way travel time by 10 minutes had the same impact on job satisfaction as a 19 % decrease in gross personal income. This equates to a reduction of £4,080 in annual gross personal income for an employee earning an average of £ 21,600.

According to Wu [18], the improvement in railway accessibility is estimated at an average of 528 yuan ($ 1 for 6,5 yuan at the ratio as of the date of writing) per month. This means that the improvement in wellbeing due to transport accessibility can be estimated at 8,1 % of the average monthly household income. At the same time, subjective wellbeing benefits from improved transport accessibility differ significantly depending on the income level of the population and urban districts. For example, the average wealth for households with 20 % income is about 163 yuan per month, compared to 898 yuan for households with 80 % income.

CONCLUSIONS

The paper has considered the social effects generated by railway transport. Even though at the initial stage any transport projects are perceived negatively (harm to the environment, increased noise levels, etc.), a deep comparative analysis shows the superiority of rail transportation in a number of parameters (Pic. 4). Data reported by Deloitte [7] confirm the superiority of railway transport in terms of generated effects:

• Each kilometre travelled by car or motorcycle, rather than by railway, results in the emission of an additional 0,05 kg of CO_2 equivalent.

• At a cost of $ 59,53 per ton of CO_2 equivalent, each kilometre travelled by rail instead of a car saves 0,27 cents on emissions.

• Cost of accidents on road transport ($/km) is of 0,1062, while on railways it is of 0,0139, so road transport generates almost eight times more road traffic accident costs per kilometre than railway; each rail trip that replaces a car trip reduces accident costs by about $ 1,40. The cost of one fatal accident (value of statistical life) is $ 8,8 million.

The effects identified in the work should be considered by government and private investors when selecting and approving projects, as well as when making decisions on funding, which will ultimately improve efficiency and save budgetary resources. Further research in this area can be aimed at developing approaches to the quantitative and monetary assessment of these effects, considering countries' and regional features.

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